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SOME PROPERTIES OF EPIKARST DRAINAGE SYSTEM IN GUNUNG KIDUL REGENCY, YOGYAKARTA, INDONESIA

By
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ABSTRACT

The aim of the paper is to enlighten some properties of epikarst drainage system due to various local condition. Karst area covered in this paper is the western part of Gunung Sewu Karst extending nearly 2/3 of the karstified areas. It belongs to Gunung Kidul Regency, Yogyakarta Special Province, Java-Indonesia.

The variables identified and measured in the field include secondary porosity and the general feature of geomorphological and hydrological condition. Laboratory analysis was also conducted to acquire data of rock, infilled material porosity and texture of infilled material.

Drainage system of Gunung Sewu Karst varies in some localities. The properties of epikarst drainage system is seemingly governed by lithology and geological structure. Since lithology and geological structure are controls of karst type, the drainage system variation is related to the karst type as well.

INTRODUCTION

Karst areas are well known for their complex or unisotrop aquifer. The complexity is governed by the secondary porosity of joint-leaded solution. Articles and textbooks on karst (Bocker, 1974; Gunn, 1981; Atkinson, 1985; White, 1988; Ford and Williams, 1989) show the complexities of karst aquifer. Karst aquifer comprises three components, namely conduit, fissure, and diffuse. Conduit aquifer is characterized by its turbulent moving water, fissure aquifer has a combination of laminar and turbulent water, whereas diffuse aquifer is dominated by Darcy's flow (laminar). Due to its heterogeneity, the concept of aquifer can not completely be applied in karst area. Gillison (1996), accordingly, prefer using drainage system instead.

The main storage of karst areas is the epikarst zone (Linhuan, 1986; Klimchouk, 1997; Sauter, 1997), a near surface zone subjects to intensive solution process. The main factors governing its properties are climate, lithology and geological structure.

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Articles on epikarst in temperate climate show some significant variation. The Gunung Sewu Karst in Gunung Kidul Regency with its various lithology and geological structure is likely to undergo various stage of karstification that give rise to complex epikarst properties as well. The Gunung Sewu Karst lies on Wonosari Formation and comprises corral in the southern part and bedded limestone in the northern part (Surono, 1992). Sutoyo (1994) identified that the Gunung Sewu Karst consists of *wackstone*, *rudstone*, *packstone*, and *framestone*. Dominant geological structure develops in the area is joint, however joint intensity differs in some localities. This paper accordingly aims at studying the properties of epikarst drainage system due to various local conditions.

METHOD

Sample areas were selected purposively regarding landform pattern depicted on 1:50,000 black and white aerial photograph mosaic (Appendix 1.). The variables identified and measured in the field include secondary porosity, lithology, epikarst thickness and infilled material. Secondary porosity was assessed two dimensionally from rock outcrops by counting the percentage of solution cavities in one square meter area. Lithology was identified trough hand specimen, epikarst thickness was predicted from the depth of intensive solution zone. Infilled material and lithology were sampled for further laboratory analysis. Laboratory analysis was conducted to acquire data of rock porosity, infilled material porosity and water content of infilled material. The porosity of limestone was assessed under polarization microscope. Drainage system was drawn based on field observation especially the occurrence of spring and urderlied impermeable rock.

THE STUDY AREA

Site and Climate

Karst area covered in this paper is the western part of Gunung Sewu karst extending nearly 2/3 of karstified areas. It belongs to Gunung Kidul Regency, Yogyakarta Special Province, Java-Indonesia (Figure 1). The area lies in southern hemisphere between 7°57' and 8°12' latitude.

The climate prevails in the Gunung Kidul is strongly influenced by monsoon that brings about two seasons (wet and dry). Wet season occurs during October to April and dry season in May to September. The annual rainfall derived from 14 rain gauge stations varies between 1500 mm and 2986 mm.

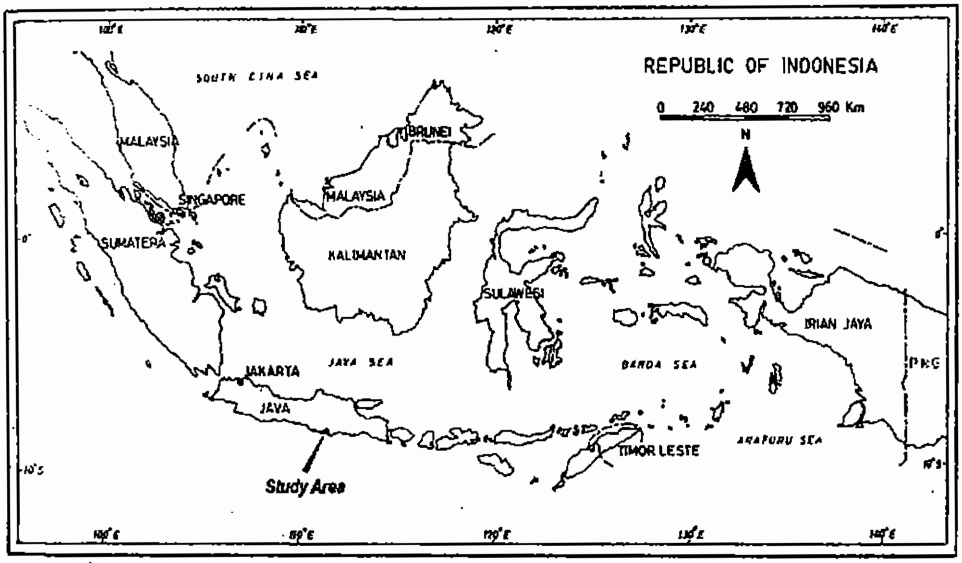


Figure 1. The Study Area

Morphology and Geological Setting

The Gunung Sewu Karst belongs to the southern plateau of Java Island (Pannekoek, 1949), stretching east-west and sloping gently southward. Its maximum height is 480 m from mean sea level. This plateau borders high cliff along the south coast. The north-eastern part was faulted and moved down forming Wonosari Basin. Karstification does not take place in this area contrasted to the southern and eastern part. The karstified area currenly is a hilly topography that is characterized by multiple hills called as *Gunung Sewu* (thousand hills).

The study area geologically is a part of Wonosari Formation consisting of corral limestone in southern part and bedded limestone in the northern part (Surono et al, 1992) deposited during early Miocene to late Pliocene (Bemmelen, 1949; Suyono, 1994). The Wonosari Formation was uplifted during late Pliocene and early Pleistocene. Due to compression to the south and north direction, this area was subject to active deformation brought in intensive jointing and faulting.

RESULTS AND DISCUSSIONS

The karst area in Gunung Kidul Regency varies in some localities, and exhibit different types of karst landform (Haryono et al., 1999; Haryono and Day, 2001). The first type lies in the westernmost area covering the area of Panggang Sub District. The second type develops in the south fringe and middle area stretching East-West (Paliyan and Tepus Sub District). The third type is located in the north-east part of the karst Gunung Kidul (Suthern Ponjong Sub District) and some parts of near coastline (Krakal beach). The first karst type is characterized by polygonal karst with cockpits develops on it. The second karst type is dominated by labyrint karst characterized by dry valley and surface drainage networks. The third karst type area has undergone planation processes forming scattered residual hills. Those three areas are depicted in Figure 2.

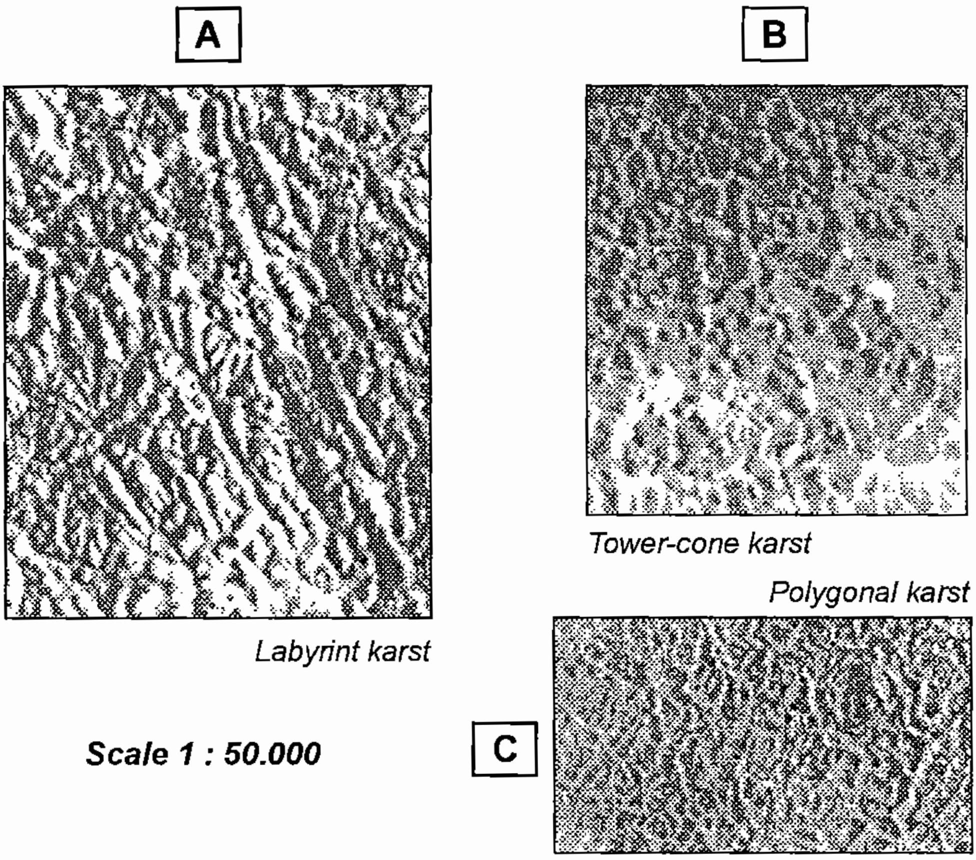


Figure 2. Sample areas of the labyrint (A), tower-cone (B) and polygonal (C) karst of Gunung Kidul Regency depicted in black and white aerial photograph

The first karst type characterized by cockpit is likely resemble the polygonal karst of Darai Hills-Papua Newguine (Williams, 1973). However polygonal karst in the study area exhibits differently in respect to interfering fluvial process. The fluvial process takes place more intensive here than that in Darai Hills, forming surface drainage networks. The stream networks result in a lengthy higher order and larger doline area instead of closed depression. Surface valley is heading southward as it is in line with regional slope. Polygonal karst lies in hard corral reef limestone. Minor joints and solution cavities intensively occur in the area reaching 25 meters in depth. In the western side, the area borders escarpment separating the karst area with alluviated graben of Bantul.

The labyrint type (second) is strongly controlled by major joints and faults give rise to intensive development of dry valley networks, even, more intensive than that in polygonal karst described previously. Close depression does not develop well here. In some localities, cone karst develops forming a combination of cone and labyrint karst. Intensive minor jointing and karren are also the other characteristics of the area bring about large secondary porosity. Rocks forming this area is hard corral reef limestone.

The third karst type in Gunung Kidul is already in the stage of mature development. This area seems to be the most ideal keglekarst proposed by Lehmann (1936). Considering karst development model of Ford and Williams (1989) it is considered a tower karst, a karst type characterized by scattered isolated hills with corrosion plain. However, the tower is not the same as those in either Maros-Indonesia (McDonald, 1975; Sunarto, 1997) or Guilin-China (Sweeting, 1990). Here, the isolated hills is a conical one. Therefore, the author prefers using tower-cone karst instead of tower karst. The tower cone karst in Gunung Kidul is lack of minor joint and karren not like that in labyrint and polygonal karst. The rock is dominated by *wackstone*. It is likely to be the reason for being lack of karren. Wackstone is weak rock that is easily soluted and not strong enough to withstand in the form of karren. As karren has been developed, in short time it is degraded either by solution or physical weathering.

The epikarst zone in those three area, consequently, also exhibit differently. Schematic features of epikarst zone in those three areas are depicted in Figure 3. Epikarst zone in labyrint karst is the thickest comparing to those in polygonal and tower-cone karst. The thinnest epikarst zone is encountered by tower-cone karst. Epikarst zone in polygonal differs from those in two others in regard to the underlain less permeable rock (brecciated limestone or volcanic breccia).

Drainage system

Water enters karst system trough complex pathways depending on the epikarst zone properties. The three areas described earlier exhibit different drainage system. In general, drainage system of epikarst zone is showed in Figure 4. Furthermore the discussion will be focused on the those sample areas.

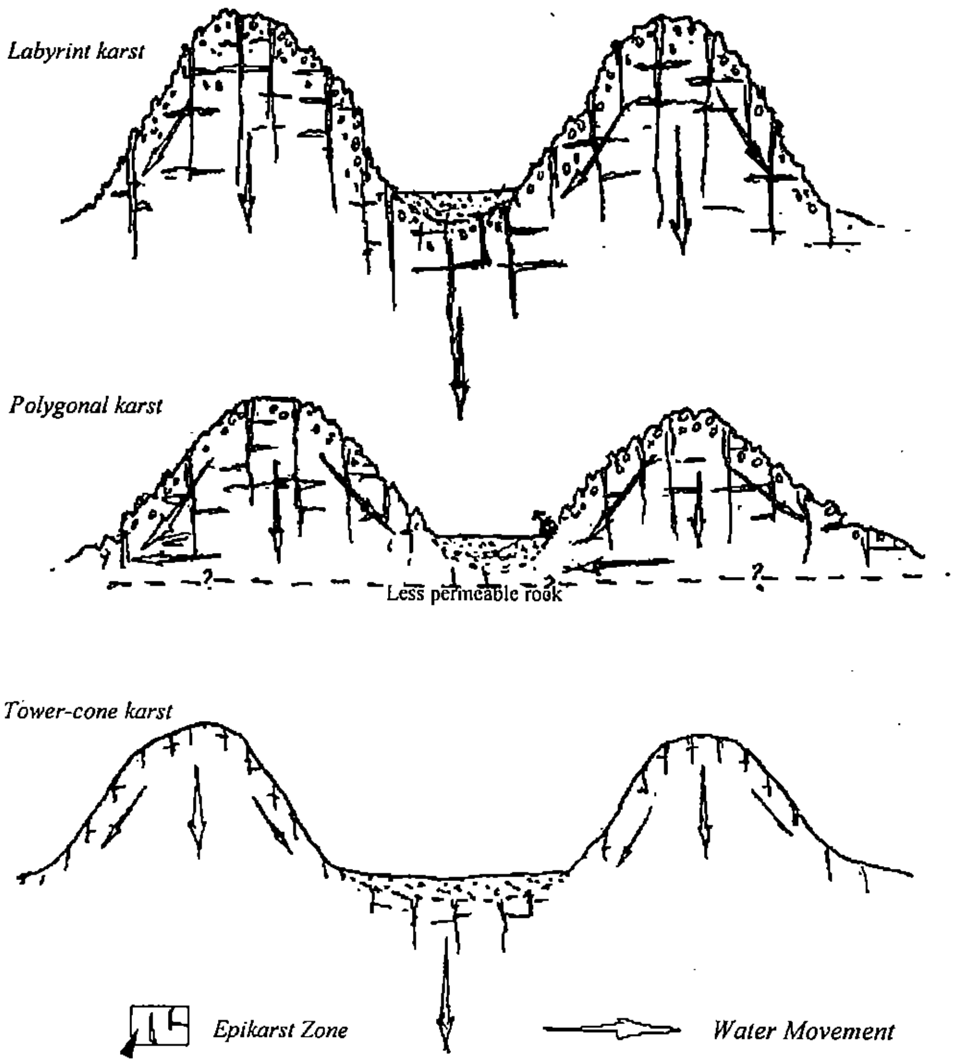
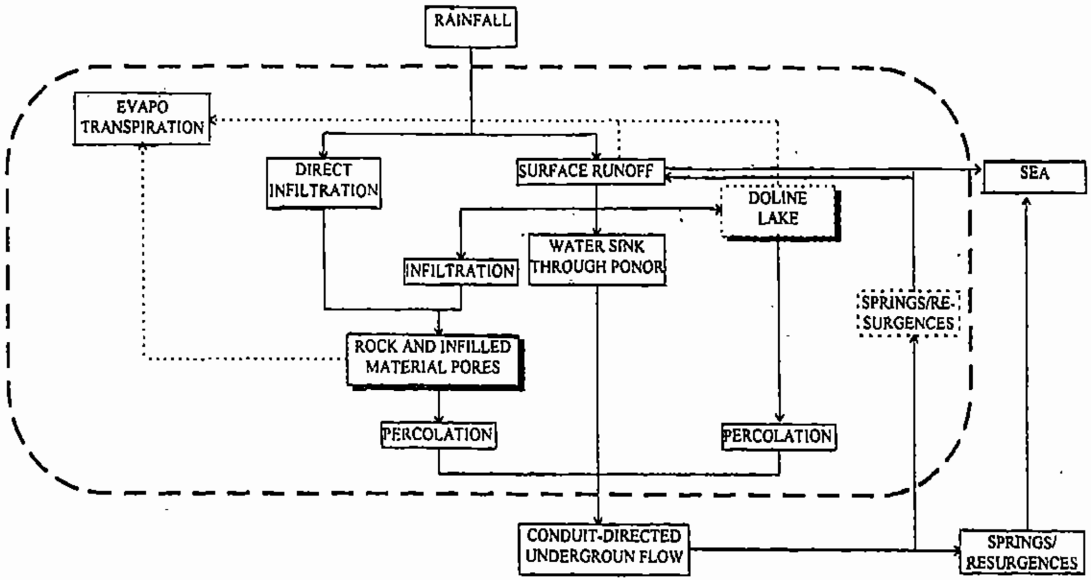


Figure 3. Schematic features of epikarst zone in labyrint, polygonal, and tower-cone karst in Gunung Kidul Regency



THE RELATIF AMOUNT OF WATER OCCURENCE IN THREE DIFFERENT AREAS

Water pore in infilled material	Polygonal-cone & labyrint-cone > Tower-cone
Water pore in rock	Tower-cone > Polygonal-cone & labyrint-cone
Surface runoff	Polygonal karst > Labyrints-cone karst > Tower-cone karst
Springs	Poligonal karst > Tower-cone karst > Labyrint
Dolin lake	Polygonal kars > Tower-cone karst and Labyrint

Process of water movement
Storage
Arbitrary
Epikarst Zone

Figure 4. Drainage system of epikarst zone in Gunung Kidul Regency

In the westernmost area where polygonal karst develop well, water undergoes the shortest ways due to thin limestone. The basement in the area is breccia sloping south-eastward. The shallowest breccia appears in the west escarpment in the depth of 15 to 35 m (in the south) and getting deeper to the north. Springs emerge both in escarpment and in the plateau.. Briefly, water from precipitation will infiltrate and percolate trough interstices (primary, secondary and infilled material) in the karst system, emerge as springs. On the way infiltrate and percolate, water is stored temporally in infilled material, rock interstices, and solutional cavities, as well as doline lake.

The labyrint-cone karst has different properties of drainage system. Here, the secondary porosity is abundance. The basement of the area is volcanic breccia in the depth of approximately 600 m (Surono et al., 1992). Therefore, spring is not found in this area. Water from precipitation infiltrate directly to endokarst system. Some water become surface runoff through valleys leading to either ponor or doline lake. Springs are found near the Wedi Ombo beach where an intrusion occurs there. Mostly, water enters this system be a underground river through conduits.

The tower-cone karst lies in thick soft-bedded limestone. Therefore this area experiences the same drainage system as labyrint karst. Springs are not found here due to no shallow impermeable bed. Water mostly infiltrates and percolates. via either intergranuler interstices or fissure. Though secondary porosity is not as extensive as those in polygonal and labyrint karst, the joint system is high enough to transmit water. The main storage of the area is intergranuler porosity. As mentioned previously, highly porous wackstone is dominant rock here. The other storage in this area is soils. Doline lake scatters in some areas.

Porosity

Porosity of epikarst zone comprises three components, namely intergranuler porosity (primary porosity), cavities porosity (secondary porosity) and infilled material porosity. The percentage of those three porosity types varies in some localities. In the labyrint and poligonal karst, the porosity from the most to the least important respectively are secondary porosity, infilled material porosity, and primary porosity. This phenomena is likely to be the same as that of Huntoon's finding in China (1992). Yet, the tower-cone karst of which the rock is wackstone shows different properties and does not support what has suggested by Huntoon. Here the porosity properties is seemingly in vice versa, the porosity is dominated by intergranuler porosity, followed by secondary porosity and infilled material porosity. The percentage of porosity in those three areas is presented in Tabel 2.

Table 2. The Porosity of Epikarst Zone in Gunung Kidul Karts

KARST TYPE	CHARACTERISTICS	POROSITY (%)		
		PRIMARY	SECONDARY	INFILLED MATERIAL
Poligonal karst	Shalow hard corral limestone, intensive karren and solution cavities. Abundant springs feeding surface drainage system.	1.1-14.0	22-52	40.0-58.9
Labyrint karst	Thick hard corral limestone, intensive karren and solution cavities, intensive dry valley network. No springs found.	13.0-16.6	22-52	36.6-40.2
Tower-cone karst	Thick soft limestone (wackstone), lack of karren, clustered isolated cone with planation surface, no springs found.	23.1-48.2	< 10	20.6-31.9

Water content and hydraulic conductivity of infilled material

Water content as describe by Fetter (1988) is the weight of contained water, divided by total weight of the soil mass. Water content of infilled material from six locations in the karst Gunung Kidul varies from 21,42% to 34,93% (Table 3). Those value is comparably high. As the soils texture is varies from silty clay loam to clay those value is reliable and not far from that described by U.S. Department of Agriculture, *Yearbook*, 1955. Hydraulic conductivity accordingly, predicted from texture is between 10^{-9} - 10^{-4} meter/second.

This low permeability is likely the key role of karst aquifer to maintain the continuity of under ground river flow. Though the secondary porosity due to diaklast and cavities is high, karst aquifer is able to hold excess rainfall during dry season feeding to underground river system. In this case, most of cavities in epikarst zone is infilled by residual material/soils. Sample profile of epikarst zone is depicted on Figure 5.

Table 3. Water Content of Infilled Material of Gunung Kidul Karst Area

TNO	SAMPLE LOCATION	TEXTURE *	WATER CONTENT * (%)	HYDRAULIC CONDUCTIVITY** (cm/sec)
1.	Bedoyo	Clay	24,47	10^{-9} - 10^{-6}
2.	Payak	Silty clay loam	21,42	10^{-6} - 10^{-4}
3.	Wotawati	Silty clay	21,75	10^{-6} - 10^{-4}
4.	Semugih	Clay	34,93	10^{-9} - 10^{-6}
5.	Klepu	Clay	26,34	10^{-9} - 10^{-6}
6.	Panggang	Clay	25,05	10^{-9} - 10^{-6}

Sources: * Laboratory analysis ** Predicted from texture (Fetter, 1988)

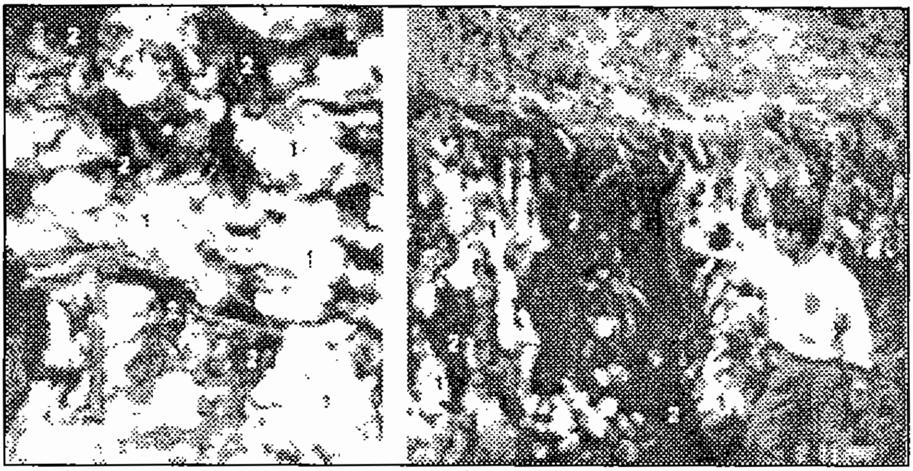


Figure 5. Sample profile of epikarts zone

CONCLUSION

Drainage system of Gunung Sewu karst varies in some localities. The properties of epikarst drainage system is seemingly governed by lithology and geological structure. Due to the lithology and geological structure controls karst type, the variation of drainage system is related to the stage of karst type as well.

Karst area in Gunung Kidul Regency comprises three karst sub type, namely polygonal, labyrint, and tower-cone karst. The relative amount of water occurrence in three different areas are 1) water pore in infilled material (polygonal-cone & labyrint-cone > tower-cone); 2) water pore in rock (tower-cone > polygonal-cone & labyrint-cone); 3) surface runoff (polygonal karst > labyrint-cone karst > tower-cone karst); 4) springs (polygonal karst > tower karst > labyrint); 5) doline lake polygonal kars > (tower-cone karst and labyrint). Low hydraulic conductivity is the key role of karst aquifer to maintain the continuity under ground river flow.

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Appendix 1. Sample areas (A, B, C are decipted in Figure 2)